DOE Canister Analysis – MCO and 24-inch FW canister

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Providing for safe, efficient disposition of DOE spent nuclear fuel

Presentation Outline

- *Completed Drop Activities*
- *Results from FY-99 Activities*
- *MCO Analysis*
- *ISFP Analysis*
- *Remaining Activites*

Drop Efforts Completed

- *NSNFP initiated analysis and proof testing effort to provide timely support to major decision points*
  - *FY99 demonstrated 18-inch standardized DOE SNF canister functionality performance with margins (drops higher than current repository-defined drops) permitted repository acceptance of standardized canister*
  - *FY03 analytical evaluations of 24-inch standardized DOE SNF canisters, Foster Wheeler modified standardized canisters, and MCOs predicted drop responses to help define future testing to support repository license application*

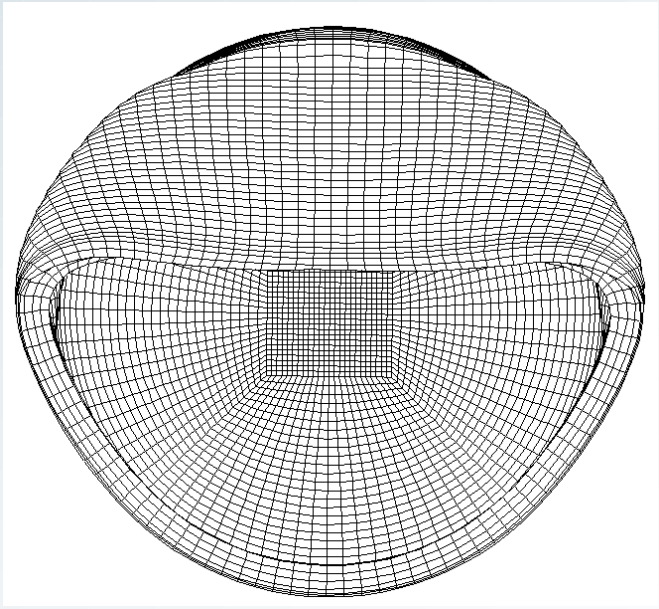
FY-99 Effort

- *10 CFR 71.73(c) drops chosen to envelope changing repository criteria (at that time), have known industry criteria to compare responses against, and to provide broader use (via margins) to DOE SNF sites*
- *Completed eight drop tests per 10 CFR 71.73(c):*
  - *30-foot drop onto an essentially unyielding horizontal surface*
  - *40-inch drop onto a 6-inch diameter bar*
- *Performed one test to simulate a drop onto a waste package (or transportation package) during the loading sequence*

Computer Analyses

- *Used the general purpose finite element analysis computer program ABAQUS/Explicit*
- *Modeled plastic material behavior with 20% increase in the stress-strain curve to account for dynamic strengthening (strain rate effects) of the material (more later)*
- *Resulting deformations acceptable and the computer predictions matched very well*

Drop Test 04 Versus Analysis Results



- *Impact angle of 45 degrees*
- *Deformations of skirt matched very well, within 6%*

Strain Results

Canister	Peak Equivalent Plastic Strains (%)					
	Pressure Boundary Components			Skirts and Lifting Rings		
	Outside	Middle	Inside	Outside	Middle	Inside
18-15-00-01	7	3	6	91	17	75
18-15-06-02	9	3	10	107	21	94
18-15-90-03	40	15	26	10	10	10
18-15-45-04	33	9	36	52	33	84
18-15-80-05	57	19	42	24	20	19
18-10-90-06	44	17	31	21	10	18
18-10-90-07	62*	22*	42*	11	10	10
18-15-PW-08	20	7	18	38	38	38
18-15-PP-09	39	14	40	-	-	-

** Predicted strains due to rigid internals. Actual strains believed to be more like test 18-10-90-06.*

Drop Test Results

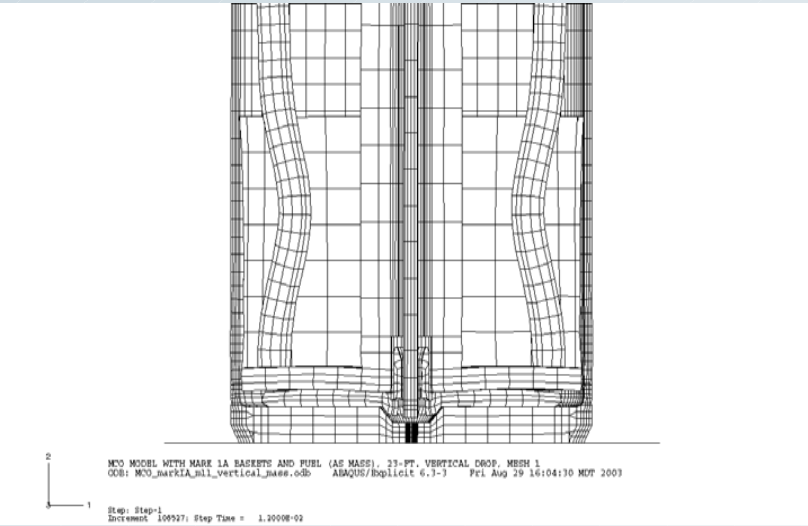
- *All standardized canisters passed a pressure test, holding 50 psig air steady for one hour*
- *Observed no changes in initial weld seam flaws when comparing pre- and post-drop radiographs*
- *The four most heavily damaged standardized canisters had helium leak rates <10^{-7} std cc/sec*
- *Standardized canister deformations acceptable and internals responded as desired*

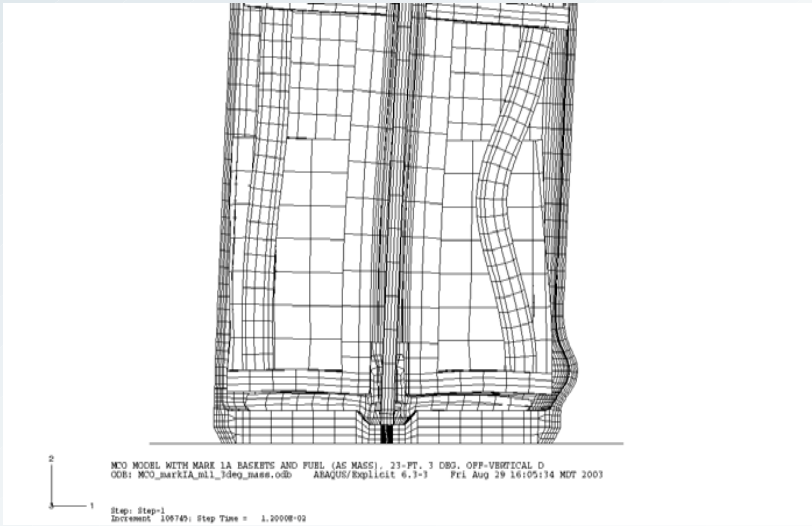
Analytical Evaluations

- *Analytically predict drop responses of DOE SNF canister:*
  - *18-inch Std. canister*
  - *24-inch Std. canister*
  - *18-inch ISFP canister*
  - *24-inch ISFP canister*
  - *MCO*
- *Analytical evaluations covered repository and 10 CFR Part 71.73(c) drop events (30-foot) except MCO which considered repository drops only*

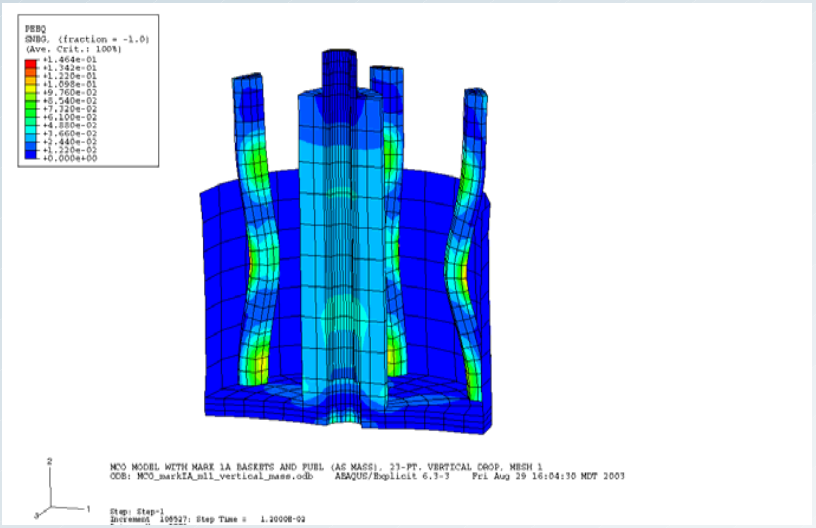
MCO Internals (Mark 1A)

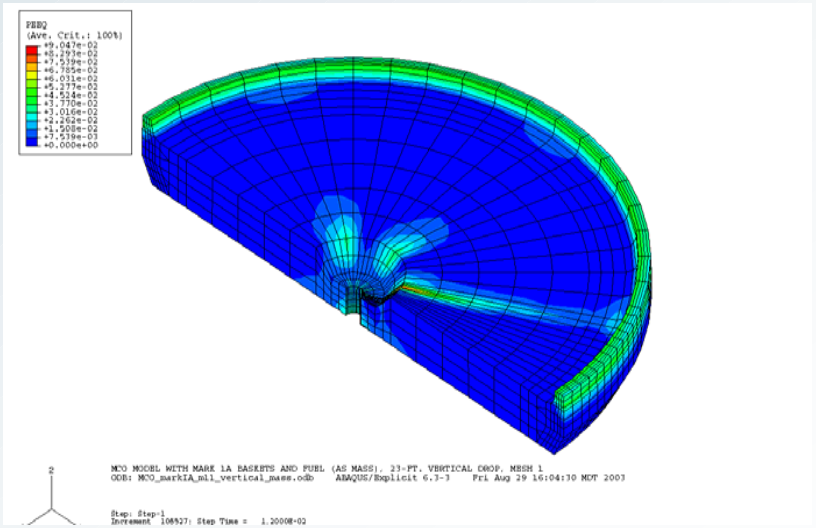
MCO Mark 1A, 23-ft Drop



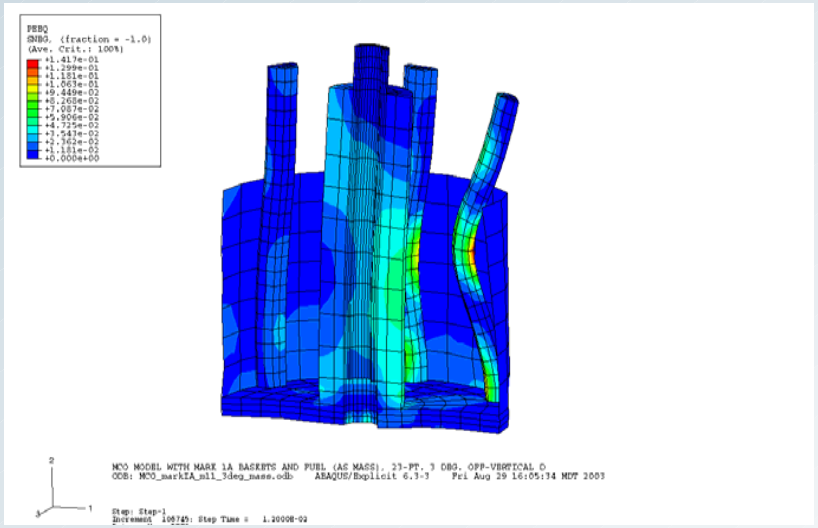


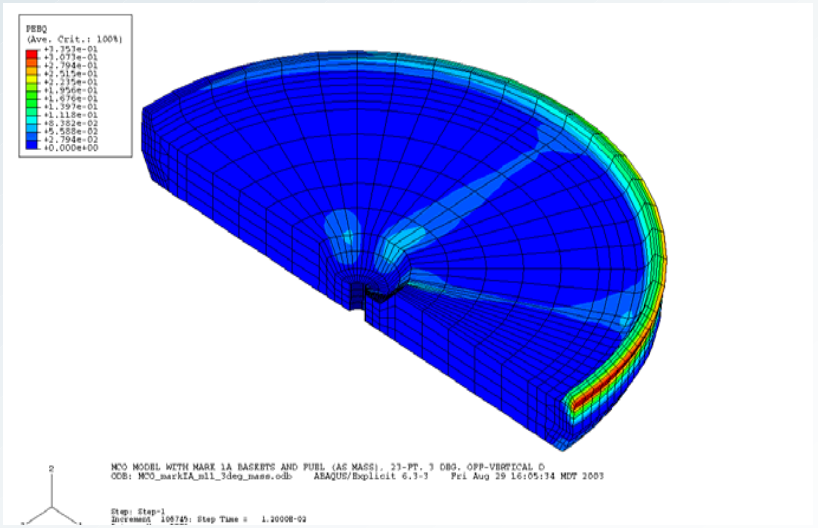
MCO Mark 1A, 23-ft Vertical



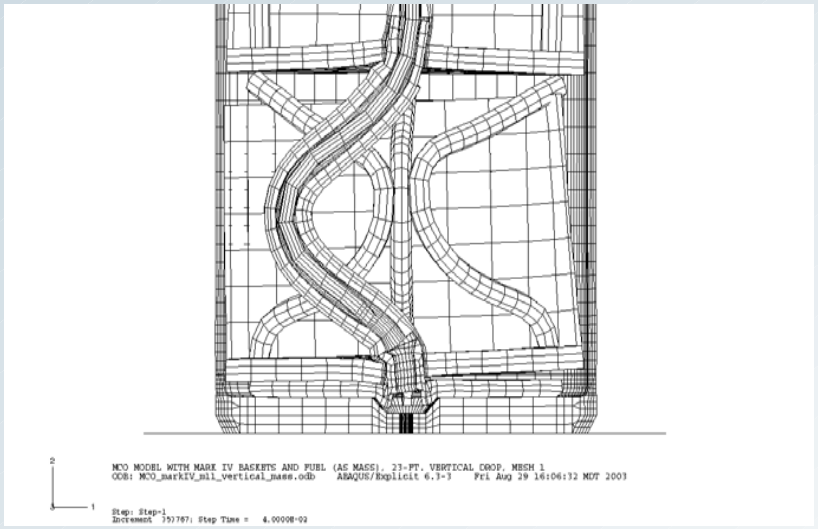


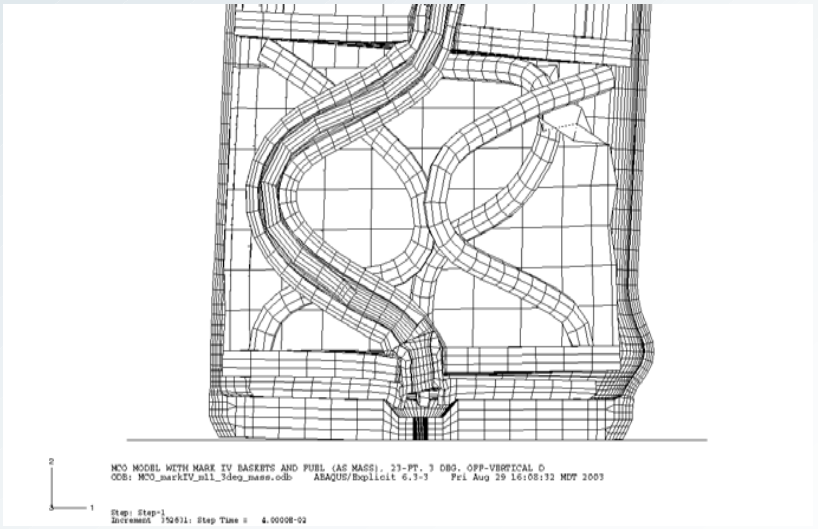
MCO Mark 1A, 23-ft 3° Angle



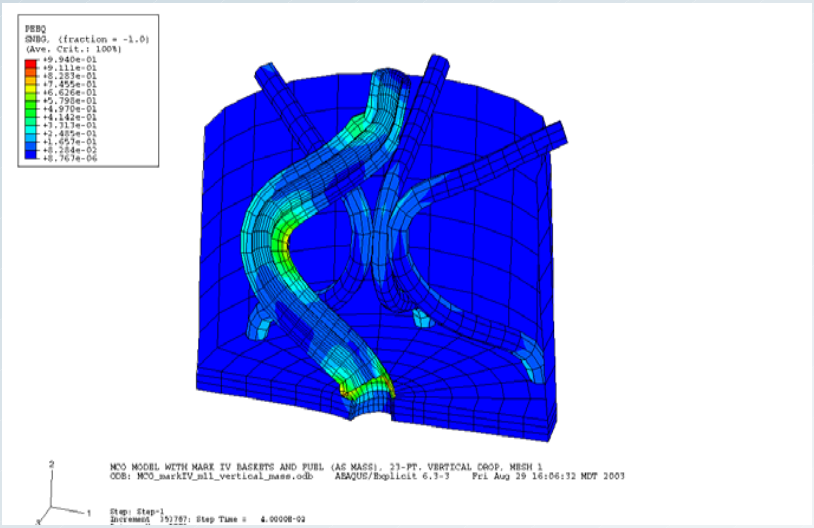


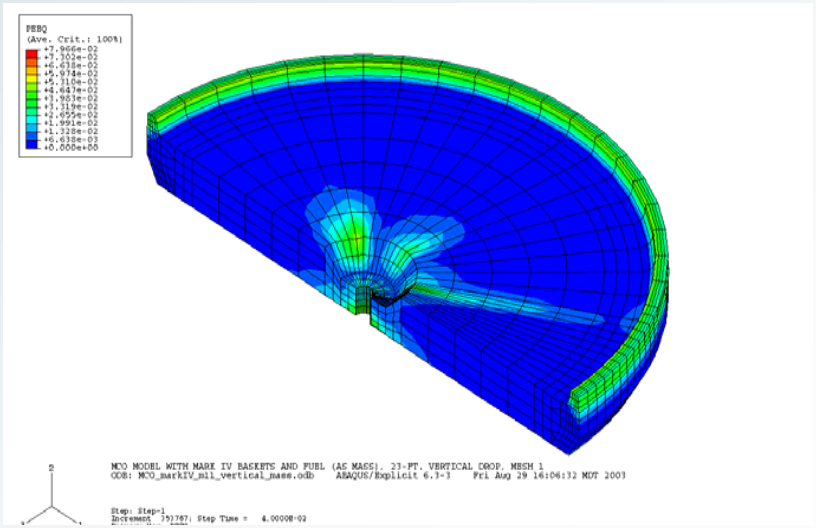
MCO Mark IV, 23-ft Drop



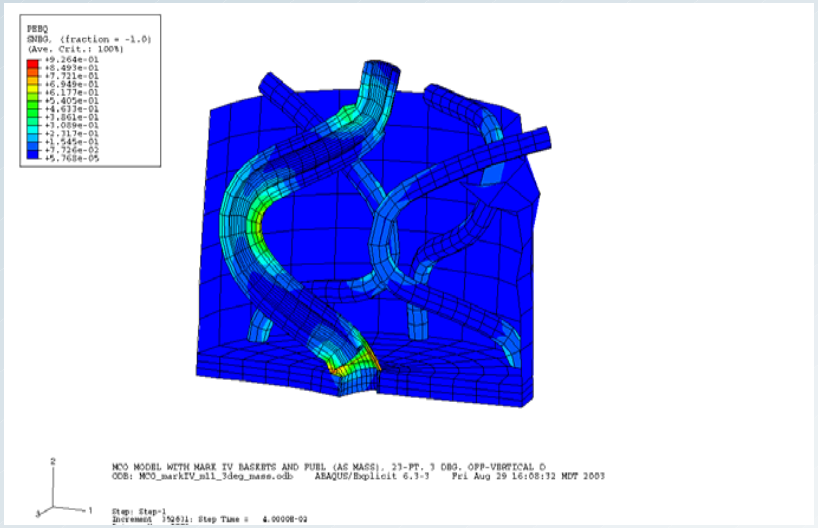


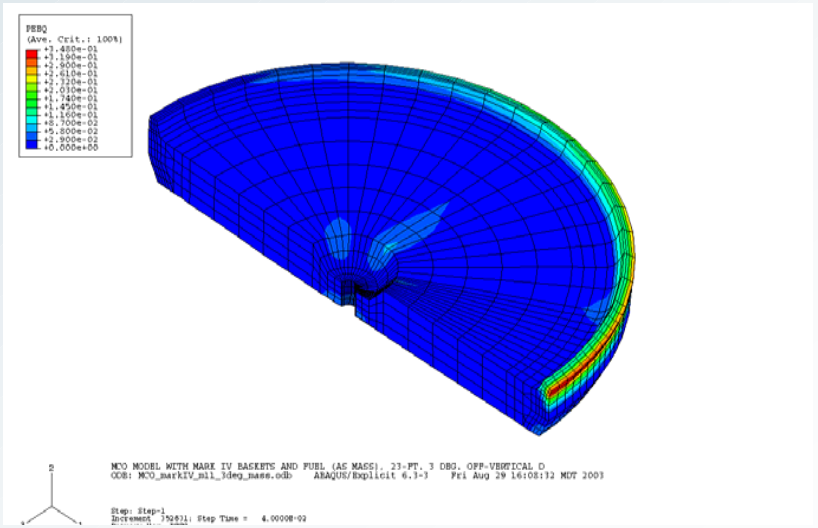
MCO Mark IV, 23-ft Vertical





MCO Mark IV, 23-ft 3° Angle

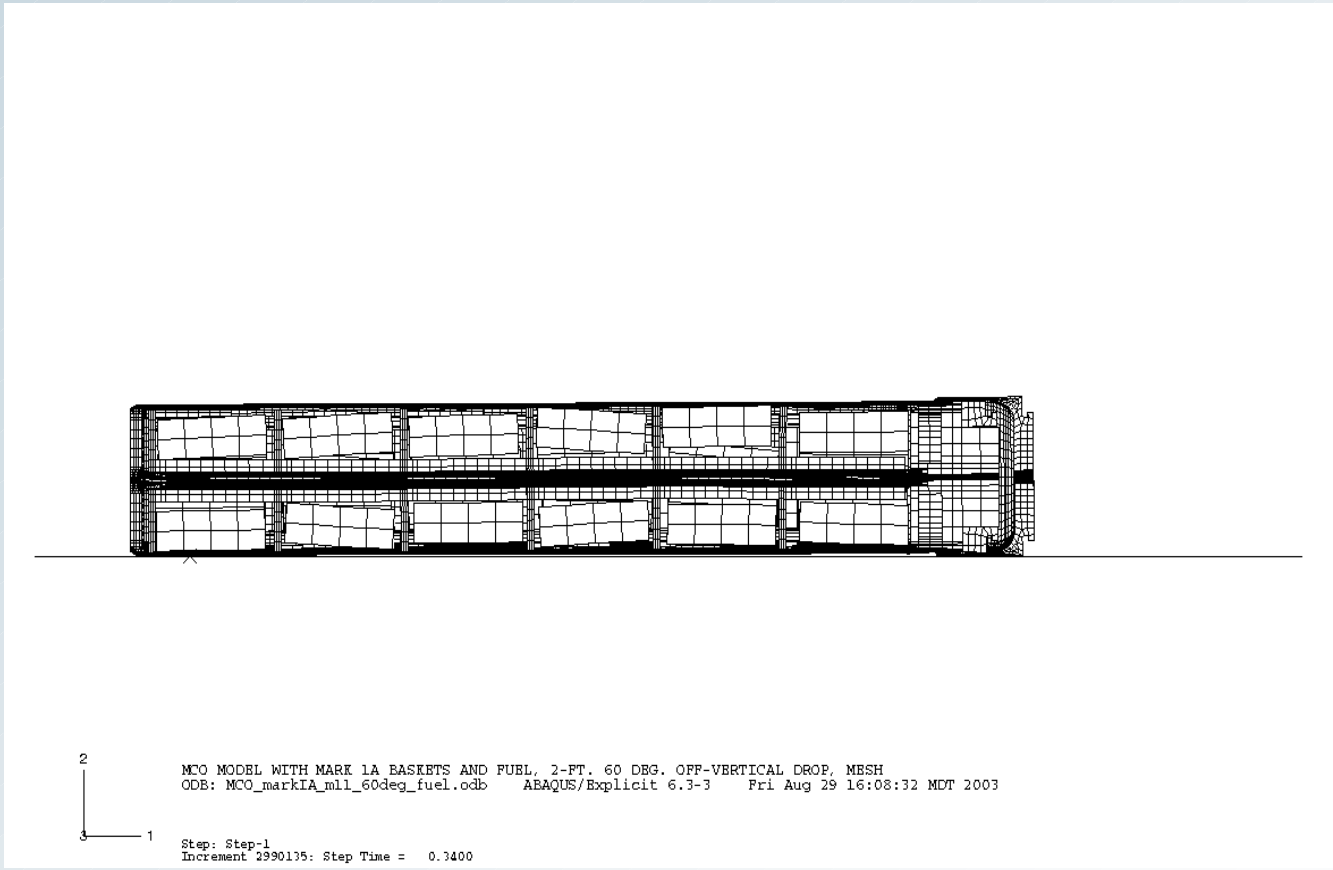




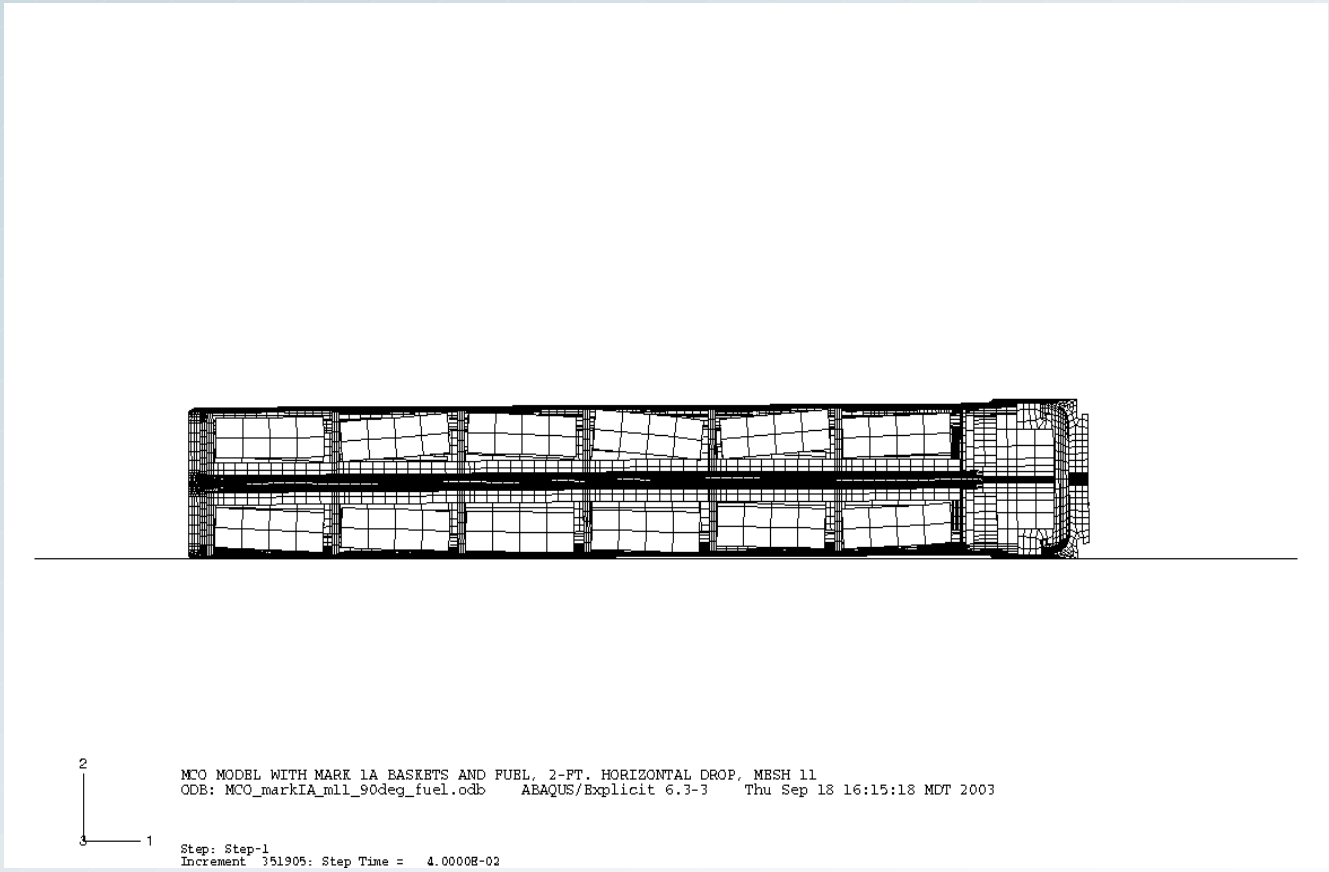
MCO 23-ft, Vertical Drop

- *A capacity-loaded MCO, with either Mark 1A or Mark IV fuel baskets, would maintain containment during and after the required repository 23-foot vertical drop onto a flat, rigid surface. This was true with a zero or 450 psig internal pressure present.*
- *Though experiencing much higher strains than occurred in the 23-foot vertical drop event, it is also expected that the MCO would maintain containment during and after the 23-foot near vertical (1 and 3 degrees off-vertical) drop events as well.*

MCO Mark 1A, 2-ft 60° Angle

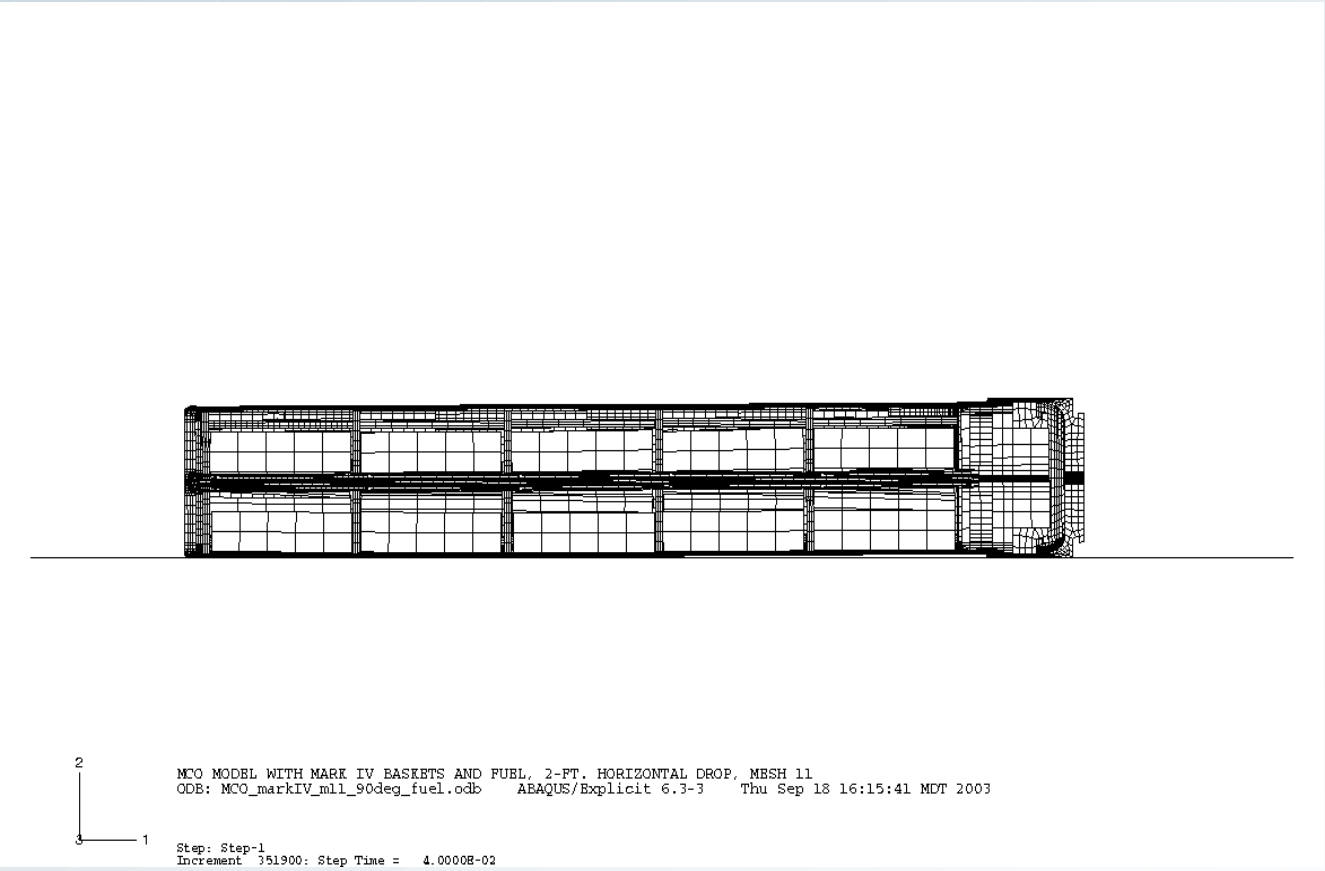


MCO Mark 1A, 2-ft 90° Angle

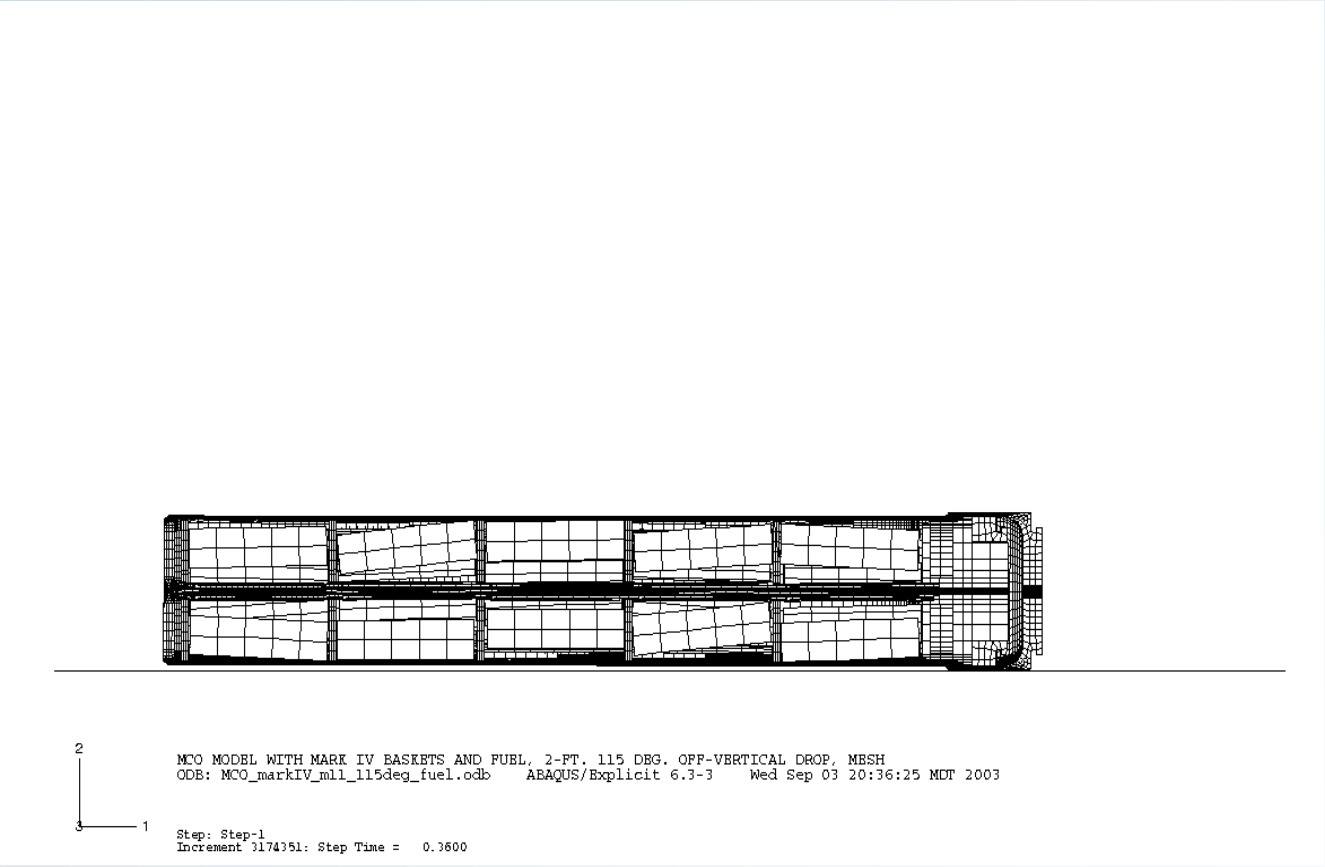


MCO Mark IV, 2-ft 60° Angle

MCO Mark IV, 2-ft 90° Angle



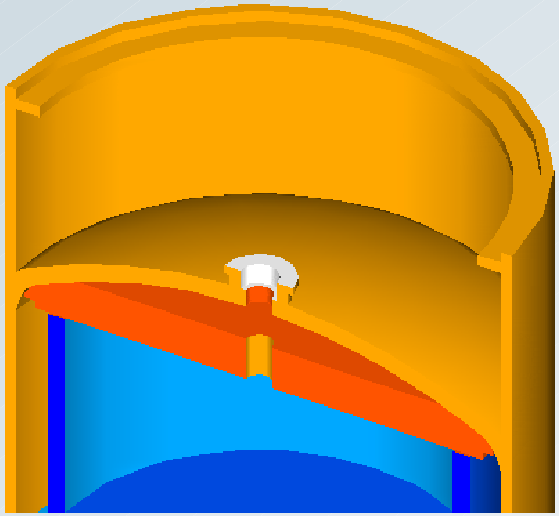
MCO Mark IV, 2-ft 115° Angle

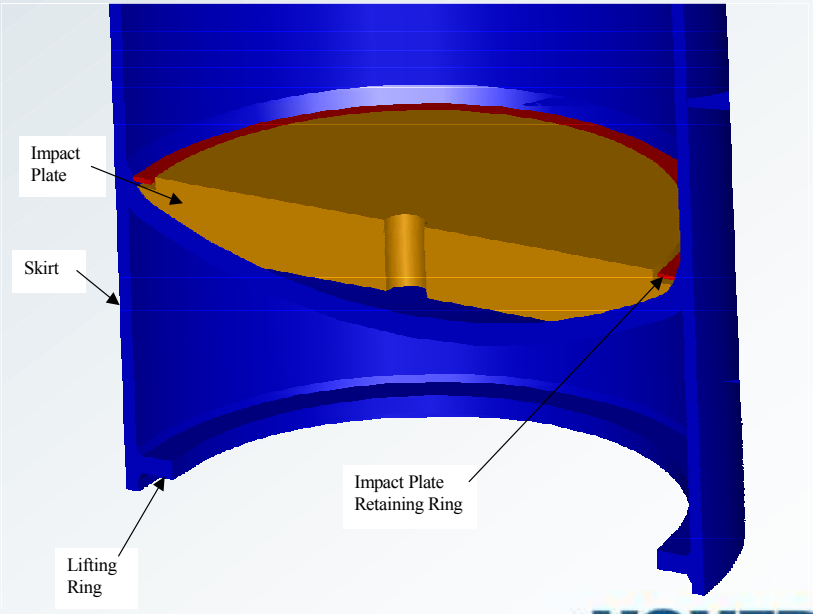


MCO 2-ft, Worst Orientation

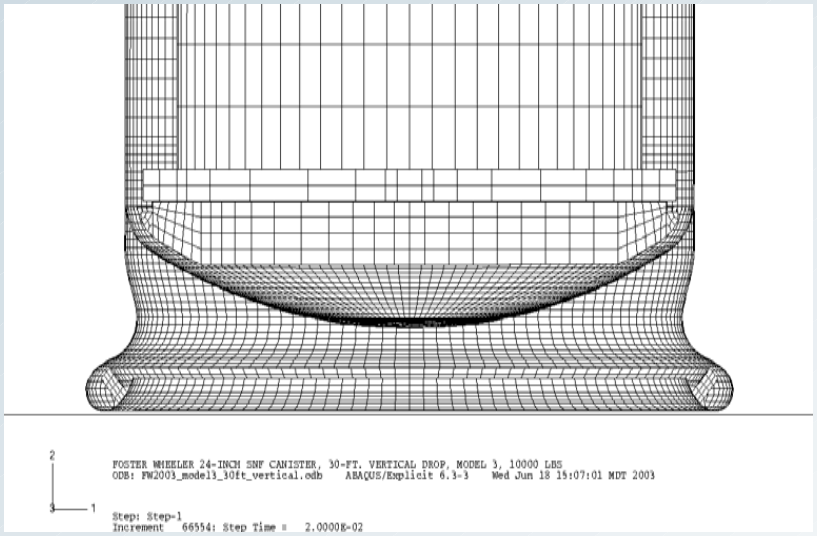
- *Drops of 60^{o}, 90^{o}, and 115^{o} from vertical were evaluated*
- *A capacity-loaded MCO, with either Mark 1A or Mark IV baskets, would maintain containment during and after the required repository 2-foot worst orientation drop onto a rigid surface.*

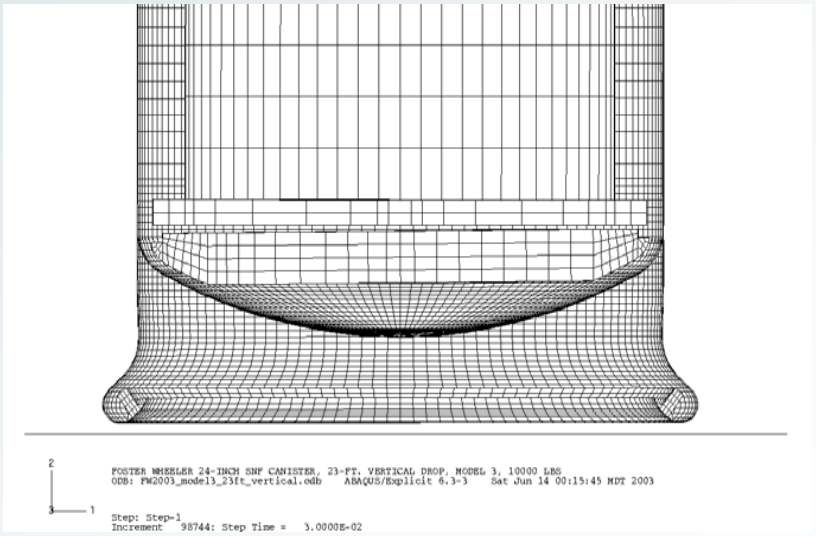
ISFP Canister Configuration



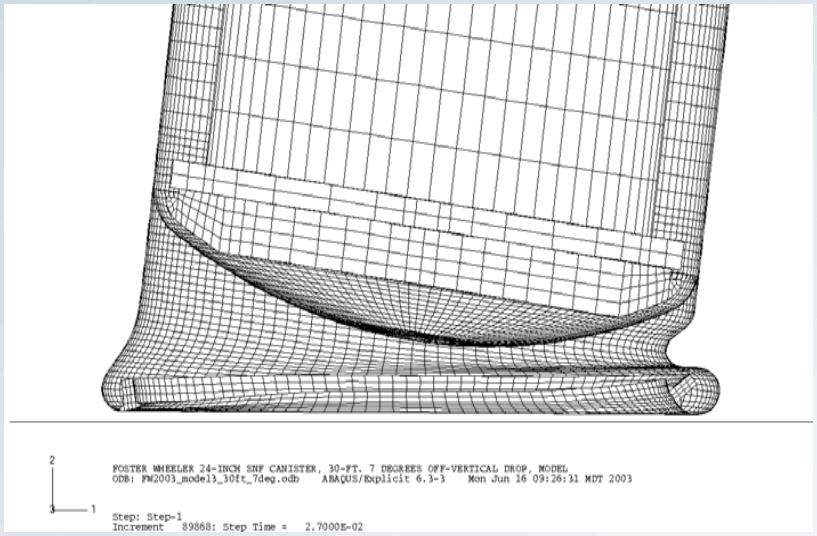


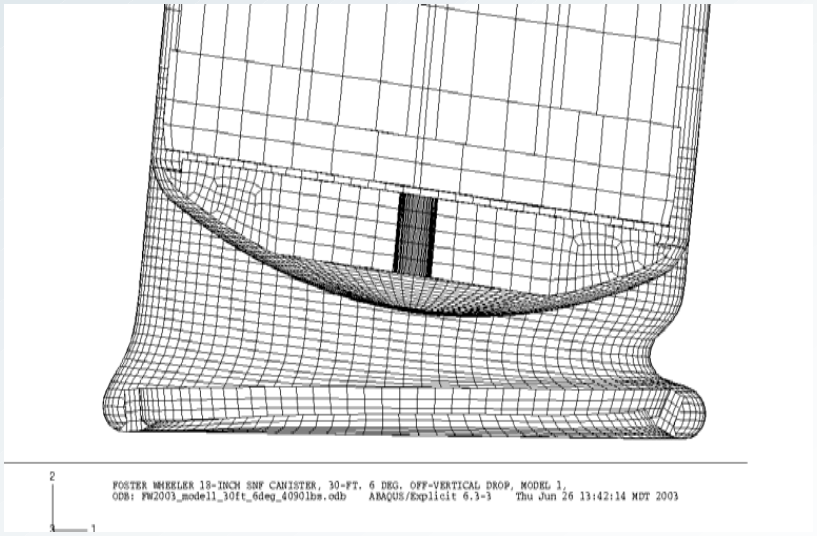
ISFP Canister, 30 & 23-ft Drop





ISFP 24-in. and 18-in. Corner





ISFP 24-inch Canister

Drop Height (Feet)	Angle From Vertical (Degrees)	Peak Equivalent Plastic Strain (PEEQ) %								
		Lower Head			Lower Skirt			Upper Head		
		out*	mid*	in*	out*	mid*	in*	out*	mid*	in*
30	0 t = 0.020	3 {6}	0.3 {0.6}	2 {4}	41 {45}	18 {16}	56 {54}	5	0.4	2
30	7 t = 0.027	0.2 {0.7}	0 {0.1}	0.1 {0.6}	86 {76}	19 {31}	57 {60}	2	0	2
30	45 t = 0.032	18 {18}	10 {9}	22 {15}	57 {95}	30 {33}	106 {117}	1 {***}	0 {***}	1 {***}
30** (34)	70 t = 0.090	47 (49) {36}	18 (18) {17}	41 (42) {35}	51 (52) {74}	31 (30) {41}	68 (67) {58}	58 (66) {57}	25 (27) {23}	27 (29) {48}
30	90 t = 0.010	38 {34}	19 {16}	17 {22}	11 {7}	6 {3}	7 {5}	36	18	16

{ } Numbers from 2003 standardized canister analysis

ISFP 18-inch Canister

Drop Height (Feet)	Angle From Vertical (Degrees)	Peak Equivalent Plastic Strain (PEEQ) %								
		Lower Head			Lower Skirt			Upper Head		
		out*	mid*	in*	out*	mid*	in*	out*	mid*	in*
30	½ t = 0.018	3 [7]	1 [3]	2 [6]	61 [91]	21 [17]	53 [75]	5	0	5
30	6 t = 0.024	0.7 [9]	0.1 [3]	0.3 [10]	88 [107]	23 [21]	58 [94]	0.5	0	0.5
30	45 t = 0.024	22 [33]	10 [9]	16 [36]	59 [52]	31 [33]	106 [84]	-	-	-
30** (33)	80 t = 0.060	33 (34)	17 (17)	29 (30)	31 (33)	18 (19)	25 (26)	48 (48) [57]	24 (24) [19]	25 (25) [42]
30*** (34)	90 t = 0.010	31 (32)	18 (19)	18 (19)	11 (12)	6 (6)	7 (7)	30 (32) [40]	17 (18) [15]	21 (23) [26]

[ ] Numbers from 1999 standardized canister analysis

Plastic Strain Comparisons

- *Analytical evaluations yielded the following predicted maximum plastic equivalent strain per canister:*
  - *18-inch Std. canister* *57%* *(FY99)*
  - *24-inch Std. canister* *57%*
  - *18-inch ISFP canister* *48%*
  - *24-inch ISFP canister* *66%*
  - *MCO* *22%* *(repository only)*
- *Effort provides ability to compare predicted strain responses and helps guide future testing efforts*

Planned MCO Drop Tests

- *Different design, no skirt, twice as heavy*
- *Different material*
- *Repository drops impact directly on containment material*
- *MCO baskets are predicted to significantly deform*
- *Two drop tests identified*
  - *Vertical 23-foot drop for most drop energy possible and significant basket deformation validation*
  - *Two-foot worst orientation due to highest containment strains*

Planned 24-inch ISFP Drop Tests

- *24-Inch ISFP canister (Tetra Tech FW DOE SNF canister design)*
  - *Plastic strains similar to the standardized DOE SNF canister*
  - *Only identified use of 24-inch standardized DOE SNF canister is for ISFP*
- *Two drop tests identified*
  - *Slapdown drop due to highest containment strains*
  - *45-degree drop to validate significant skirt response, plug interface, and gain friction insights*

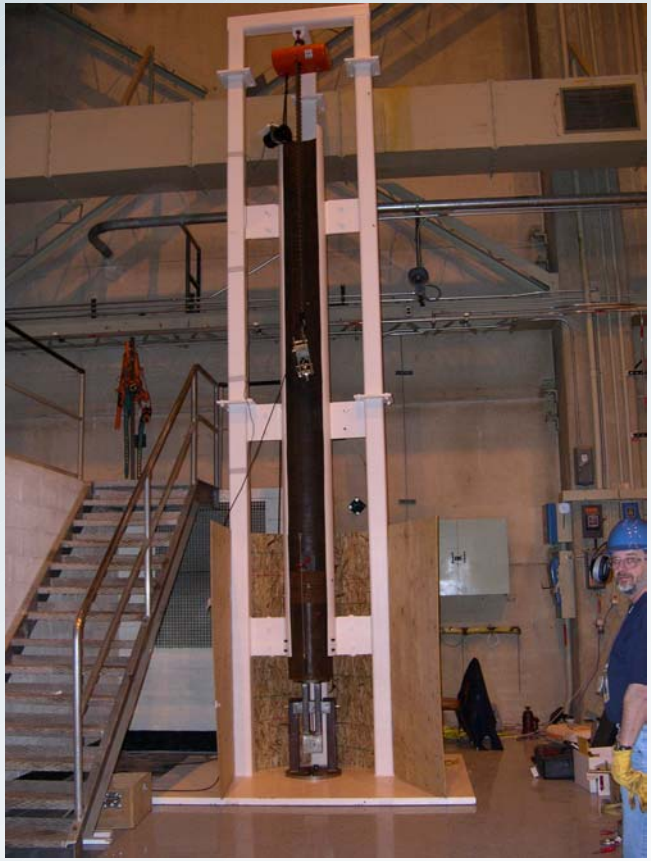
Conclusions

- *MCO will maintain containment*
  - *Provided vertical drop maintained*
  - *Baskets will be severely damaged*
- *ISFP canisters will maintain containment*
  - *Within analysis error, strain similar to standardized canister*

High-Strain Testing

- *Canister analysis assumed 20% increase in material strength under high strain*
- *Test device designed and installed at TRA*
- *Planned testing of 304L and 316L to validate the analytical assumption*

High-strain Test Device



Setup Testing Results